A High Speed Rail connection between Northern and Southern California

Abstract: Given that for any California high speed scheme the greatest revenue potential lies in forging a popular transit connection between Northern and Southern California any statewide California high speed rail scheme has a competitive and a cost problem; airline travel times through this corridor are one-half projected rail transit times and constructing a suitable rail corridor through urban areas is going to be expensive. One move that could meet both challenges; run high speed rail cars throughout the BART system. This will be a legal possibility if, as now seems likely, the Federal Railway Administration may waive crash survival requirements to build rail cars strong enough to survive a crash; provided that the train position detection system and braking systems that apply are robust enough so that crash risks are extremely remote. When these stringent separation conditions are met a compliant system may operate lightly constructed rolling stock similar to European or Japanese high speed trains or BART trains on the same track.

One-seat-rides within walking distance of prolific traffic generators such as San Francisco's Financial Center, Downtown San Jose and Oakland, and the UC Berkeley Campus may produce a faster origin to final destination travel time than present airline service with far less personal disruption. As explained below BART can accommodate double its current peak train traffic by applying a moving block separation system and adding more cars. Building costly new track parallel to BART's most crowded trunk line under Market Street in downtown San Francisco would definitely not be necessary as shown below. Nor would the increasingly expensive Trans-Bay Terminal be needed.

One innovation required to realize the full potential of a CAHSR-BART combination —split trains— would actually increase average CAHSR speed, enhance schedule reliability and sharply reduce costs of a three train per hour frequency for the majority of users.

Some new high speed track routes would be extremely valuable to Bay Area commuters. A San Jose to Altamont Pass branch for instance would parallel a crowded commuter route that would open the possibility for a strong commitment of local matching funds.

Introduction: Planners for the California High Speed Rail initiative seem to have taken to heart the motto of architect/planner Daniel Burnham, "Make no little plans ; they have no magic to stir men's blood and probably themselves will not be realized." The current CAHSR scheme has at least one route within 30 miles of most large urban areas in the state with the objective of significantly increasing long distance transit capacity while minimizing additional land use, noise, pollution and cost. Given the recent cluster of rail transportation tax increase referendum successes ranging with 70 to 80% approval votes in the San Francisco Bay it would not surprising that a CAHSR bond referendum will pass in the near future. But will the present CAHSR scheme achieve these worthy objectives?

Rail Potential: Rail transit technology is uniquely suited to accommodate high volumes on single one-way track. New York's 4 &5 and E & F lines carry over 40,000 passengers per hour per track. Some New York City Subway lines exceeded 60,000 passengers per hour per track before 1960. The Downtown San Francisco BART could accommodate 30,600 seated passengers per hour per track by applying a 'moving block' train detection system while adhering to BART's present train separation safety standards combined with a 46 second critical station dwell period. (See http://gulliver.trb.org/publications/tcrp/tcrp_rpt_13-b.pdf figures 3.12 and 3.13. and see Appendix A at the end of this paper.) Current peak scheduled train frequencies on this BART trunk line provides less than 50% of its potential capacity. Given the high urban capital cost for urban rail transit right-of-way($275 million per double track route mile for the Los Angeles Red Line) it would dramatically reduce high speed rail right-of-way capital costs to share urban railway tracks for high speed interurban trains.

Regulation Changes: Until recently a careful reading of the Federal Railroad Commission operating permit rules should leave anyone to conclude that if high speed trains are to be operated on the same tracks as local service trains the local service trains would have to be built to a much higher strength standard and therefore be at least 50% heavier than is presently the case for BART system rolling stock. But on November 30, 2005 the California High Speed Rail Authority's Rod Diridon said that a Federal Transit Authority waiver was likely to be forthcoming that would allow high speed rail trains to operate in the U.S. if the brakes on all trains and train position detection systems on the tracks they use were of such quality as to render their collision probability as extremely low. Freight trains would not be allowed on any tracks used by high speed railway rolling stock operating under such a waiver. However local commuter rolling stock on isolated track could certainly be modified in order to adhere to these stringent collision avoidance standards.

CAHSR-BART Integration: This additional degree of design freedom would be an enormously significant regulation breakthrough that would permit a sharp reduction in CAHSR capital costs simultaneously with a dramatic enhancement for CAHSR access throughout major urban areas. For instance a system performance Federal Operating Waiver applied to the BART system upgraded to these stringent separation standards would open up the possibility of running high speed rolling stock throughout the BART system. In that case the distance and probable running time between Downtown San Francisco the and Altamont pass would be less using the BART route from San Francisco's Market Street through BART's Trans-bay tunnel and the Livermore Valley than the present High Speed Rail Altamont Pass proposal. The currently projected CAHSR Altamont Pass alignment alternative would require an expensive and circuitous, for San Francisco origin passengers, lower-trans-bay high speed rail crossing..

A further reduction in San Francisco to Livermore Valley Altamont Pass running time and reliability improvement could be achieved by constructing an Oakland 'Y' bypass and adding two express tracks from Fruitvale to Bay Fair. These express tracks would not only speed up interurban through trains but enable BART to provide express service between Bay Fair and San Francisco, add infill stations between Bay Fair and Lake Merritt and increase reliability for both express and local services due to the multiple-track by-pass potential. Thus a strong symbiotic relationship could evolve between BART and the CAHSR permitting a sharing of right-of-way capital costs while enabling a dramatic improvement in intra-urban service coverage and speed. No 'Trans-Bay Terminal' would be needed in the expensive to-build-in downtown San Francisco area; BART's four 30 by 700 foot platform Market Street Stations should provide enough capacity for CAHSR and BART for many years into the future.

Transfers Should be Avoided: The CHSR planners apparently expect a large and profitable ridership between the San Francisco Bay Area and Southern California, a travel market now served by a moderate cost frequent airline service running at twice the speed of the fastest projected CAHSR service. In order to compete effectively the CAHSR service must assume a significant-to-passengers quality that airlines cannot match. One strongly appreciated transit quality is a one-seat-ride to ones destination as clearly shown by a Federal Transit Administration sponsored study called 'Traveler Response to Transportation System Changes at: (http://gulliver.trb.org/publications/tcrp/tcrp_rpt_95c9.pdf). Consider the section concerning traveler response to transfers labeled: Wait and Transfer Time Savings on page 9-21 and its summary embodied in Table 9-9 on page 9-22. This study concludes that travelers find the time lost in transferring to be many times more onerous than an equal length of extra time spent in a transit vehicle. This customer aversion to transferring is shown to be particularly true for those travelers who are not very frequent users of the route as would more likely be the case the longer the distance to be traversed.

One practical solution would be to integrate CAHSR trains into an extensive system such as BART. A particularly effective CAHSR-BART form would be for high speed MU cars to diverge from the San Joaquin Valley high speed trunk line near Tracy into multiple routes and stopping patterns covering most BART stops throughout the bay area yet permitting non-stop service from the high speed trunk line split point at Tracy Junction to Downtown San Francisco and a separate non-stop train to San Jose's Golden Triangle.

Split Train Advantages: It turns out that assembling or splitting long distance trains when approaching or leaving the sprawling San Francisco Bay Area would not only permit a material increase in the proportion riders being offered a one seat ride to Southern California but frequency, origin to destination average speed and reliability would be significantly enhanced at a sharply reduced cost due to the inherent nature of a split train service for the following reasons:

1. Frequent one seat rides from most BART stations to Southern California would be possible while simultaneously avoiding an increase in the high speed trunk line section traffic density to such a high frequency that operating costs would be excessive and reliability would decline due to an inevitably slow recovery from delays. For example 20 minute service could be provided from heavily used stations in Downtown San Francisco and Silicon Valley; at least hourly from all other stations with trunk line expresses operating with 20 minute headways. Conceivably it would be practical to offer one seat rides to Southern California from more than 30 BART stations throughout most of the San Francisco Bay area.
2. Faster service could be provided because individual line segments would have fewer stops than a block train with a skeleton stopping pattern trying to serve the entire area. One could schedule a non-stop run from BART's San Francisco Embarcadero Station to the long distance train assembly area near Tracy (Tracy Junction) in the San Joaquin Valley. Another section could start in Richmond make selected BART stops through Berkeley and Oakland and then continue with no other stops to Tracy Junction. Another section could start at the Oakland Airport, combine with the Dublin BART train in San Leandro and continue making all local stops on an extended BART local service to Tracy Junction.
3. Reliable on-time service could be more readily achieved due to the distributed nature of a multiple destination route system. A delay to a single train section would not usually hold back other sections of an assembling long distance train; especially if that delay is on a branch not used by most sections headed for the trunk line train assembly point or when the delay occurs along a multiple track section. In case the assembled trunk line train did not wait for a delayed section for more than 3 to 5 minutes the delayed section would not be forced to wait for the through express connection for more than an extra 17 minutes if the trunk line through train service maintained a 20 minute headway.
4. Some new route segments needed for the CAHSR System would also be quite valuable for local commuter service, thus opening the possibility for strong local funding for right-of-way construction costs. For example an 80 mph route from Tracy Junction to San Jose roughly parallel to the present Altamont Commuter

Express route would save an hour each way compared to present ACE schedules. Rolling stock utilization rates would be high on CAHSR collection runs with many intermediate stops because as commuters are being distributed along routes headed away from local commuter sources simultaneously long distance rail riders could be boarding the same cars.

Split train operation has a long illustrious history both in the San Francisco Bay area and especially in Chicago:
1. Within the last five years Muni light rail cars from different lines were combined into single trains for Market Street Subway runs.
2. The Oakland Key lines combined cars for run to the San Francisco Destination Ferry slip starting in 1925.
3. Electric MU split trains were once operated by Chicago's elevated lines, the South Shore (The only interurban street railway still running in the U.S.) the North Shore to Milwaukee and especially the Chicago, Aurora and Elgin where 52 line trains a day were assembled or split on that particular railway.

Some Incompatibility Issues:

1. BART's 1000 VDC third rail vs. the usual 25,000 volt AC on overhead catenary usually found on today's new long distance rail electrification projects. The answer is to build high speed rail stock that interfaces exactly the same as BART rolling stock to the !000 volt third rail. The CHSR MUs must also be able to connect to a 1000 VDC current source in line with the couplers from car to car and to an electric locomotive. Each electric locomotive would run only on track where overhead 25,000 VAC power was available especially on the San Joaquin Valley high speed trunk line and would also provide enough added traction power to sustain a 220 mph train running speed.
2. BART's 1.676 m track is the broadest gauge in wide use in a significant portion of the world's rail infrastructure; specifically in India. Note: the Indian Railway system was initiated by British designers already quite familiar with the 1.435 m gauge then as now dominant in the England and the U.S. One should also reflect on the fact that when designers sought great speed a broader gauge than in general use was chosen. Brunel's Great Western Railway in England had a 2.134 m gauge. The 1845 Gauge Commission found the 2.134 m gauge was superior in speed, stability and safety than on the more extensive 1.435 m track gauge. Japan's brilliantly successful Shinkansen uses a 1.435 m gauge instead of the 1.067 m extant in the rest of the country. But the most important consideration: a broad gauge train would be more likely to remain on its track during an earthquake.

Conclusion: The most elegant approach for producing a fast, convenient, and cost effective high speed rail service is to integrate local and statewide rail services on the same track. The shared track approach facilitates the fast and convenient collection and dispersal of passengers in broad urban areas for fast long distance rail service. The distributed nature of split train services enhances the system designer's ability to produce a high origin to destination average speed and maintain the most reliable schedules possible.

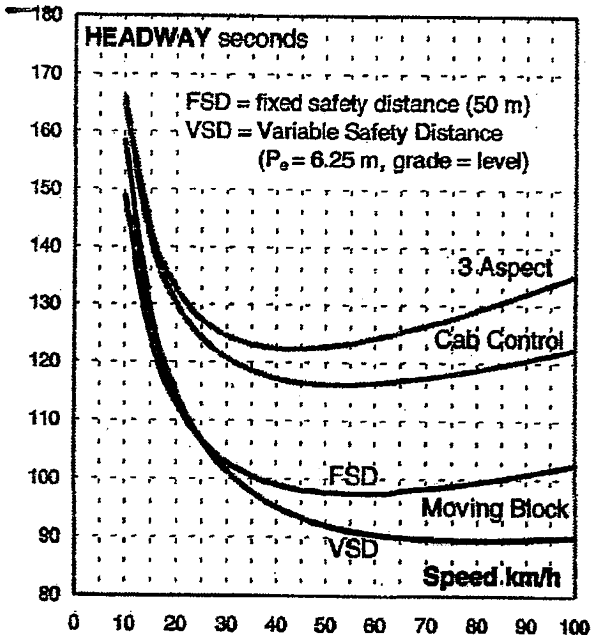

Figure 3.12 Moving-block headways with 45-sec dwell and 20-sec operating margin compared with conventional fixed-block systems

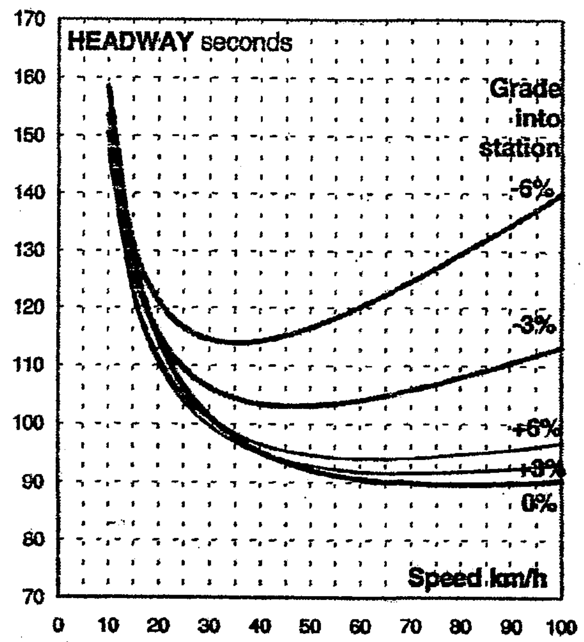

Figure 3.13 Effect of grades on a moving-block signaling system with variable safety distance

moving-block system with a speed variable safety distance shows the lowest overall headway. The difference between the two methods of determining the safety distance represents an eight second difference in the minimum headway—pointing out the importance of selecting the best method when a close headway is required.

The elasticity of moving-block headways with respect to voltage fluctuations will be negligible as the time to clear the plat-form is not a component in calculating the moving-block signaling system headway. The effect of grades is shown in Figure 3.13.

Downgrades (negative) into a station significantly reduce the minimum headway while positive grades have little effect.

3.9 TURN-BACK THROUGHPUT

Correctly designed and operated turn-backs should not be a constraint on capacity. A typical minimal terminal station arrangement with the preferred[41] center (island) platform is shown in Figure 3.14. The worst case is based on the arriving

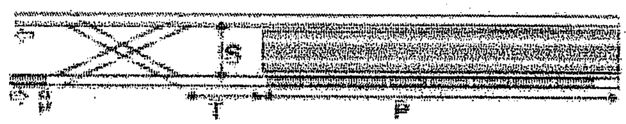

Figure 3.14 Terminal station track layout[42]

train (lower left) being held at the cross-over approach signal while a train departs. It must, moving from a stop, traverse the cross-over and be fully berthed in the station before the next exiting train (lower right) can leave. The distance involved is

$$D_a = P + T + CS \qquad \text{Equation 3-22}$$

where
- D_a = approach distance
- P = platform length
- T = distance from cross-over to platform
- S = track separation (≡ platform width +1.6m)
- C = switch angle factor
  - 5.77 for #6 switch
  - 6.41 for #8 switch
  - 9.62 for #10 switch

The time for this maneuver is expressed as

$$t_a = 2\sqrt{\frac{2D_a}{a_s + d_s}} = 2\sqrt{\frac{2(P+T+CS)}{a_s + d_s}} \qquad \text{Equation 3-23}$$

where
- t_a = approach time
- a_s = initial service acceleration rate in m/s^2
- d_s = service deceleration rate in m/s^2

[41] While side platforms reduce the track to track centers and so reduce the maneuver time, they require passengers to be directed to the correct platform for the next departing train. This is inherently undesirable and becomes more so when a train cannot depart because of a defect or incident and passengers must be redirected to the other platform.

[42] The diagram shows no run-on space beyond the station platform. Where there is little or no such space, mechanical or hydraulic bumpers should be provided.

One Direction Single Track Capacity

Appendix A: **Minimum Station Headway with BART's Projected Moving Block Signal System :**

In the case where the minimum signaling headway is achieved by starting both the 1st and 2nd trains start at the same time. Both trains are always separated by a minimum safety distance $s_o = 60$ ft.

For both trains the distance traveled (S) while undergoing constant acceleration is: $S = \frac{1}{2}at^2 = v^2/2a$ when $t = v/a$

The minimum variable distance the 2nd train must always remain behind the 1st train as the 2nd train's speed increases: $S_{br} = (V_{x2})^2/2b_r$

The safety braking rate (b_r), applicable to the second train in this case, is the maximum braking rate permitted by current BART safety standards when train separation must be assured.

The 1st train's distance from start is: $S_1 = (V_1)^2/2a_1$

The distance the 2nd train will travels from its starting point is: $S_2 = (V_{x2})^2/2a_{x2}$

The 2nd train's acceleration rate (a_{x2}) is a dependent variable with its magnitude contingent on the values of a_1 and b_r and computed in the following manner.

The 1st train's distance from start is equal to the 2nd train's distance from start plus plus the minimum variable distance the 2nd train must remain behind the 1st train:

$$S_1 = S_2 + S_{br}$$

or:

$$(V_1)^2/2a_1 = (V_{x2})^2/2a_{x2} + (V_{x2})^2/2b_r$$
$$(V_1)^2/2a_1 = (V_{x2})^2[(1/2a_{x2}) + (1/2b_r)]$$
$$(V_1/V_{x2})^2 = a_1[(1/a_{x2}) + (1/b_r)] = a_1/a_{x2} + a_1/b_r)$$
$$(V_1/V_{x2})^2 = a_1(1/a_{x2} + 1/b_r)$$

Let $R = V_1/V_{x2} = a_1/a_{x2}$ $\qquad R^2 - R - a_1/b_{r2} = 0$

Maximum acceleration and braking rates:

$a_1 = b_2 = b_n = 4.4$ ft/sec^2

Safety constrained braking rate: $b_r = 2.93 \approx 3$ ft/sec^2 $\qquad R^2 - R - 4.4/3 = 0$

Using the quadratic formula:

$$R = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a} \qquad R = \frac{1 \pm \sqrt{1 - 4(-4.4/3)}}{2}$$

$R = 1.823$

The total close-up distance between the first trains's starting position and the second train's new position is: $nl' + s_o$

$a_{c2} = a_1/R = 4.4/1.823 = 2.414$ ft/sec^2

$nl' + s_o = (V_2)^2(1/2a_{c2} + 1/2b_n)$

Let V_{c2} = equal the 2nd train's maximum velocity. $\qquad V_{c2} = [(nl' + s_o)/\frac{1}{2}(1/a_{c2} + 1/b_n)]^{\frac{1}{2}}$

nl' = the train length = (10)(70) = 700 ft

$s_o = 60$ ft = the shortest distance allowed between trains. $\qquad V_{c2} = [(700 + 60)/\frac{1}{2}(1/2.4138 + 1/4.4)]^{\frac{1}{2}}$

The maximum second train speed (V_{c2}) is: $V_{c2} = 48.7$ ft/sec = **33.2 mph**

The minimum close-up period ($h_{r\,min}$ — the time required for the second train to replace the first train stopped in the station) is:

$$h_{r\,min} = V_{c2}(1/a_{c2} + 1/b_n)$$
$$h_{r\,min} = [(nl' + s_o)/\tfrac{1}{2}(1/a_{c2} + 1/b_n)]^{\frac{1}{2}}(1/a_{c2} + 1/b_n)$$
$$h_{r\,min} = [2(nl' + s_o)(1/a_{c2} + 1/b_n)]^{\frac{1}{2}}$$
$$h_{r\,min} = [2(700 + 60)(1/2.4138 + 1/4.4)]^{\frac{1}{2}}$$

$h_{r\,min}$ = **31.23 sec**

The minimum total station headway (h_s min = 80 sec) is the sum of the close-up time ($h_{r\,min}$ = 31.2 sec), dwell time (t_d = 46 sec), and the acceleration rate change delay (t_r = 2.8 sec):

$$h_{s\,min} = t_d + t_r + h_{r\,min}$$
$$h_{s\,min} = 46 + 2.8 + 31.2 = 80 \text{ sec}$$

$h_{s\,min}$ = **80 sec./train**

(3600(sec/hour)/(80 sec./ten car train) = **45 ten car trains/hour** ridership, the system actually faced a 16 percent loss (Finn, 1997). Further exploration of the effects on VRE and other commuter rail ridership of service reliability problems, changing conditions on parallel transportation facilities, and other external factors is found in Chapter 8, "Commuter Rail."

The impact of strikes on transit ridership was the subject of a time-series analysis of the effects of major incidents on ridership in Orange County, California, including the 1979 gasoline shortage and transit strikes of 1981 and 1986. The work underscores the long-term effects a prolonged strike can have on transit ridership. The gasoline shortage caused a temporary 20 percent increase in ridership which only lasted as long as the shortage. The 1981 6-week work stoppage caused a 20 percent decrease in ridership and a prolonged multi-year negative effect on ridership levels. A shorter work stoppage in 1986 caused a similar decrease, but ridership levels returned close to normal relatively quickly (Ferguson, 1991). For an analysis of impacts *during* a strike, see the case study "Impacts of a Bus Transit Strike in the San Francisco East Bay Cities," in Chapter 10, "Bus Routing and Coverage."

UNDERLYING TRAVELER RESPONSE FACTORS

Wait and Transfer Time Savings

Service frequency changes affect the time a transit patron must wait for service, both initially and at transfer points. Increasing the frequency reduces these wait times and makes transit a more attractive travel mode. Studies of urban travel behavior show that the travel time implications of travel alternatives are a highly important determinant of consumer choices. For urban area travel to and from work, overall travel time savings are valued at roughly one-third to one-half of the wage rate, on average. The value depends on the choice situation involved, such as mode choice and path choice. Non-work travel time savings are usually valued less (Charles River Associates, 1997).

Not all components of travel time are equal in value per minute as perceived by the trip maker. Time components of the complete trip that are often referred to as the "out-of-vehicle time" are the time spent getting to and from motorized transport or waiting for the vehicle to arrive or depart. These appear to be more onerous than the time actually spent in the vehicle, the so-called "in-vehicle time." Typically, reductions in out-of-vehicle times are more highly valued than reductions in in-vehicle times, and thus more strongly affect consumer choice of mode. This finding has important service design implications

Travel demand research done using various modeling techniques has for some time suggested that transit wait time, transfer time, and walk time lumped together as "out-of-vehicle time" may be at least on the order of twice as important in mode choice as an equal time spent in the transit vehicle (Quarmby, 1967; Shunk and Bouchard, 1970; Schultz, 1991). More recent modeling efforts, utilizing advanced techniques and protocols for more precise treatment of out-of-vehicle time components, are divided between identifying out-of-vehicle time as being twice as important or four times as important as in-vehicle travel time. In the roughly twice as important category (basing out-of-vehicle time importance on the first 4.5 or more minutes of waiting for the initial bus, journeying to or from work) are Houston at 2.58 times in-vehicle time, Portland at 1.25 times and Cleveland at 2.13 times (Barton-Aschman, 1993; Kim, 1998; Parsons Brinckerhoff, 1998). In the roughly four times as important category, using the same basis of comparison, are

Minneapolis-St. Paul at 4.36 times and Chicago (bus and rapid transit) at 3.41 times (Parsons Brinckerhoff, 1993 and 1999).

An examination of over 50 work purpose travel demand models from throughout the United States found each minute of transit wait time to average 2.12 times as important as a minute of in-vehicle travel time. Ranges were from 2.72 average for urban areas under 750,000 population to roughly 2.0 for larger cities, and from 2.48 average for 1990s models to about 2.0 for older models (U.S. Environmental Protection Agency, 2000).

Newer models often afford differentiation among the out-of-vehicle time components. This capability provides mixed indications, but as discussed further in Chapter 10, transfer wait is most often shown to be of greater importance than the overall initial wait. If transit service is reasonably reliable, passengers can reduce the impact of the initial wait time by adjusting their time of arrival to more closely coincide with the transit schedule. Transfer waits, in contrast, cannot be controlled by the passenger. (The several references to Chapter 10 in this discussion refer specifically to the "Running, Walk and Wait Time" subsection within the "Underlying Traveler Response Factors" section of Chapter 10, "Bus Routing and Coverage.")

Table 9-9 gives the relative weights on travel time exhibited by the Minneapolis-St. Paul mode choice model. In this model, the relative importance of transfer wait time must be taken together with the importance of the penalty associated with each transfer to judge the degree to which travelers view transferring as undesirable. (Transfer penalties are examined further in Chapter 10.) Similarly, the relative importance of initial (non-transfer) wait time must be judged by taking the values for the first 7.5 minutes together with the values for additional wait time (Parsons Brinckerhoff, 1993).

Table 9-9 Relative Importance of Minneapolis-St. Paul Model Travel Time Components

Trip Purpose	Running Time	Initial Wait (First 7.5 min.)	Initial Wait (Over 7.5 min.)	Transfer Wait Time	Added Penalty per Transfer
Home-Work	1.0	4.36	0.88	4.36	none
Home-Other	1.0	4.00	10.78	3.77	17.27
Non-Home Based, Work Related	1.0	4.00	4.00	2.50	27.28
Non-Home Based, Non-Work Related	1.0	4.00	7.63	1.58	121.05

Notes: All values are normalized to minutes of running (in-vehicle) time. Relative importance values of 4.00 (four times as important as running time) are assumed on the basis of the home-work model calibration results. All other relationships are "originally estimated" using the 1990 Minneapolis-St. Paul survey data.

Source: Parsons Brinckerhoff (1993).

Note that in the case of the Minneapolis-St. Paul model, the time over 7.5 minutes is not viewed as even as important as running time by work trip commuters. This outcome is presumably because commuters know the schedule and can avoid a long time at the bus stop. Conversely, travelers making trips likely to be less repetitive and more discretionary apparently find the longer waits increasingly onerous, as indicated by the "Initial Wait over 7.5 Minutes" values in Table 9-9 for home-other (non-work) trips and non-home based non-work related trips.